

Differences in thermal responses in a fragmented landscape: temperature affects the sampling of diurnal, but not nocturnal fruit-feeding Lepidoptera

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Abstract. Weather is the primary determinant in butterfly activity, with temperature one of the key factors affecting the biology and behavior of most Lepidoptera. Despite evidence about the influence of temperature in Lepidoptera capture patterns, few studies have analyzed microclimatic characteristics. Most studies focused on broad geographic scales and historical climatic patterns. The present study contrasts the effect of local temperature on the capture rates of two groups of fruit-feeding Lepidoptera, butterflies (diurnal) and noctuid moths (nocturnal), in a fragmented landscape. Ten fragments with five traps each were sampled in southeast Brazilian Atlantic Forest during eight days in July-2005. We found a positive relation between mean temperature and both richness and abundance of captured butterflies, but not the noctuid moths. These differences are probably a result of the miothermic nature of moths, making the moth assemblage less dependent of solar radiation than butterflies. The differences between moths and butterflies could affect the distribution of these insects across fragmented landscapes and suggest that adult moths are probably less sensitive to changes in the amount of solar radiation than adult butterflies.

Key words: fruit-feeding butterflies, Nymphalidae, Noctuidae, temperature.

INTRODUCTION

Ehrlich (1984) stated that weather is the primary determinant in butterfly activity. Temperature is a key factor affecting most Lepidoptera because it has direct effects on larval behavior and performance, flight activity and associated behaviors such as foraging and territoriality (Broersma *et al.*, 1976; Scriber & Slansky, 1981; Hrdy *et al.*, 1996; Shirai *et al.*, 1998; Kührt *et al.*, 2005; Nabeta *et al.*, 2005; Merckx *et al.*, 2006). Many butterfly species are able to maintain their body temperature above ambient through basking and/or shivering behaviors (Kemp, 2002), such that individuals with higher body temperatures can be active for longer periods than their cooler bodied counterparts (Dudley, 1991). On sunny days some butterflies have been reported to fly for longer periods and maintain higher body temperatures than on cloudy days (Shelly & Ludwig, 1985). Temperature

is also known to affect the seasonal distribution of some species (Turner *et al.*, 1987), probability of capture in temperate regions (Yela & Holyoak, 1997; Holyoak *et al.*, 1997), and the abundance and diversity patterns of both butterflies (Turner *et al.*, 1987; White & Kerr, 2007) and moths (Brehm *et al.*, 2007; Choi, 2008).

Despite the evidence that ambient temperature influences activity patterns in Lepidoptera, few studies have analyzed the effect on a microclimatic scale (e.g. Yela & Holyoak, 1997). Most have focused on broad geographic scales and historic climatic patterns (e.g. Brown & Freitas, 2000; Menéndez *et al.*, 2007). However, anthropogenic activity is known to produce major changes in microclimatic conditions (Saunders, 1991; Vitousek *et al.*, 1997) which likely in turn could affect the insects that occupy a given habitat.

Accordingly the present study attempts to test the effect of local temperature in the capture rates of fruit-feeding butterflies and moths in a fragmented landscape. Here we ask whether there are differences in the responses of diurnal versus nocturnal Lepidoptera to average temperature, linking the possible differences with the effects of forest fragmentation among these two sets of insects.

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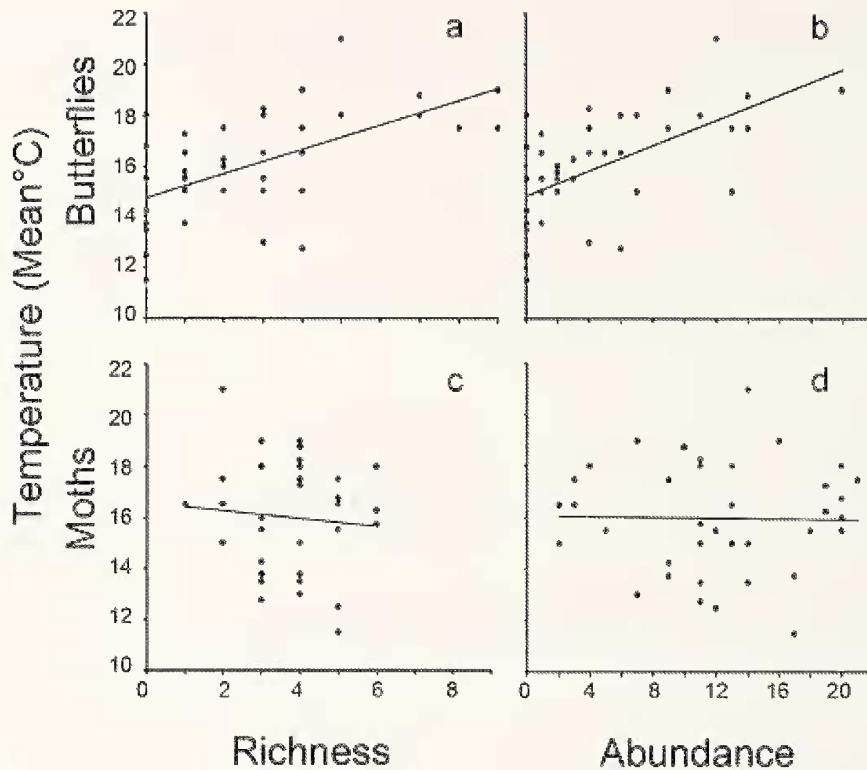


Figure 1. Linear regressions between temperature and species richness and between temperature and abundance for both butterflies and moths sampled with baited traps in a fragmented landscape in Brazilian Atlantic Forest. **a)** Linear regression between mean temperature and richness of fruit-feeding butterflies; **b)** linear regression between mean temperature and abundance of fruit-feeding butterflies; **c)** linear regression between mean temperature and richness of bait attracted moths; **d)** linear regression between mean temperature and abundance of bait attracted moths.

MATERIALS AND METHODS

Field work was carried out in the São Luiz do Paraitinga municipality (Fig. 1), São Paulo State, south-eastern Brazil (centered in 23°20' S, 45°20' W). The original vegetation of the area was mainly a dense humid forest (MME 1983); however, the process of forest fragmentation drastically changed the plant community cover across the region (Schmidt, 1949; Petrone, 1959; Dean, 1997). Today, large parts of the native vegetation has been removed with the resulting landscape now being composed of small patches of disturbed forest scattered in a matrix of farm fields and abandoned pastures and including some patches of *Eucalyptus* plantations.

Ten forest fragments were chosen at random for sampling. In each fragment, five traps were arranged along a linear transect for a total of 50 traps. Detailed information of sampling methods and the study site are given in Ribeiro *et al.* (2008).

Butterflies (diurnal) and noctuid moths (nocturnal) were sampled during June 2005. The traps remained

in the field for eight days and were visited at 48-hour intervals. During each visit bait was replaced and each captured individual was identified, marked and released. Species not determinable in the field were taken for later identification (following Ribeiro *et al.*, 2008). All butterflies were identified to species level and the moths (all Noctuidae) were discriminated as morphospecies.

Ambient temperatures were measured with a maximum thermometer at each visit. The arithmetic mean of the maximal and minimal temperature measured during the period between visits (48 hours) was used as mean temperature.

We use simple linear regression to test if there was a relationship between abundance and richness of butterflies and moths with mean temperature.

RESULTS

A total of 233 individuals comprising 27 species of fruit-feeding Nymphalidae and 475 individuals of nine morphospecies of noctuid moths were captured.

The mean temperatures recorded during the study period ranged between 11.5 and 21.0°C. We found a significant relation between mean temperature and species richness ($p < 0.0001$; $R^2 = 0.362$; $N = 40$; $y = 0.2481x + 14.84$) (Fig. 1a) and individual abundance ($p < 0.0001$; $R^2 = 0.362$; $N = 40$; $y = 0.2481x + 14.84$) (Fig. 1b) in our butterfly samples. In contrast, we did not find a significant relation between mean temperature in either richness ($p = 0.5811$; $R^2 = 0.0084$; $N = 40$; $y = -0.1608x + 16.599$) (Fig. 1c) or abundance ($p = 0.8936$; $R^2 = 0.0004$; $N = 40$; $y = -0.0079x + 16.094$) (Fig. 1d) of the moth samples.

DISCUSSION

We found a strong relation between microhabitat temperature and richness and abundance in samples of diurnal, but not nocturnal noctuid Lepidoptera. The relation between butterfly capture and temperature is likely the result of differences in daily activity of the diurnal set of species compared with the nocturnal noctuids. Despite the great variety of behaviors related to thermoregulation in butterflies (Clench, 1966), air temperature remains important in determining butterfly activity (Douwes, 1976). Thus we would expect greater butterfly activity and capture rate on hot rather than in cold days. Although weather, especially temperature, is usually considered the most important factor determining butterfly and moth diversity (Holyoak *et al.*, 1997; Yela & Holyoak, 1997; Hawkins & Porter, 2003; Brehm *et al.*, 2007; Menéndez *et al.*, 2007; Choi, 2008), few studies demonstrate significant relations between microhabitat conditions with species richness and abundance of Lepidoptera (e.g. Yela & Holyoak, 1997; Dolia *et al.*, 2008).

The differences found in diurnal versus nocturnal fruit-feeding Lepidoptera are likely the result of the latter being miothermic and therefore independent of solar radiation to enable their activities (Daily & Ehrlich, 1996). If the conclusion is correct, we would expect that butterflies in the subfamily Brassoliniæ should respond similarly to nocturnal moths, since brassolines are not as dependent upon solar radiation as other butterflies are (Srygley, 1994).

The degree of fragmentation has significant influence on microclimatic conditions, as temperature, humidity and amount of solar radiation (Saunders, 1991), with many studies of diurnal fruit-feeding Lepidoptera reporting changes in the community correlated with forest fragmentation (Krauss *et al.*, 2003; Shahabuddin & Ponte, 2005; Uehara-Prado *et al.*, 2007). The change in microclimatic conditions also affects the distribution of butterflies in forest fragments, probably because fragmentation impacts

the activity of these insects by being beneficial to heliophilous species that are more likely to displace shade-loving species. Another important alteration caused by microclimatic changes in temperature is the effects upon life-history traits of butterflies by changing daily fecundity and lifetime number of eggs of females (Karlsson & Van Dyck, 2005). However, the same effect may be less important in moths because they are not directly influenced by solar radiation (Daily & Ehrlich, 1996) and suffer only the indirect effects of the changes (e.g. alteration in leaf quality, resource offer and so on).

Both sample richness and abundance are positively correlated with mean temperature in the present study. Since trap capture is considered as a reliable measure of activity and density in fruit-feeding Lepidoptera, we can conclude that temperature had an undeniable effect in butterfly richness and abundance. However, in view of the great importance of temperature in determining the behavior and distribution of diurnal Lepidoptera, other studies are necessary to verify if this relation could be found in other habitats, with different climates and land covers.

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